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LIQUID METAL STRESS CRACKING OF COPPER NICKEL

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PURPOSE

Develop a laser brazing procedure to join small diameter copper-nickel tubing to a silver or copper substrate.

FINDINGS

The recommended brazing alloy for copper-nickel (Ref. 1) is AWS BAg-8 (72 Ag - 28 Cu). This alloy caused intergranular liquid metal stress cracking when used with the laser process. We were successful in making a crack-free laser braze using AWS BAu-4 (82 Au - 18 Ni). It is believed the success of the BAu-4 was due to its melting temperature being above the recrystallization temperature of the cold worked Cu-Ni tube.

BACKGROUND

Figure 1 shows a schematic drawing of the braze joint. Laser brazing was chosen as the joining technique because of its controlled heat input. A variety of jobs have demonstrated the usefulness of laser brazing (Ref. 2). Furnace brazing or torch brazing would both be acceptable methods for joining the materials involved; however both would have required the entire part be brought up to the brazing temperature. In this case thermal cycling the entire part was undesirable.

PROCEDURE & RESULTS

In the initial attempts to braze this joint, the silver plate was removed for a short distance around the tube exposing the copper. Figure 2 shows a photomicrograph of the copper-nickel tube tack welded to the copper. Note, without braze alloy present, there is no cracking apparent.

The braze alloy was introduced as 200 mesh powder. The parameters used with the Raytheon SS500 laser are shown in Table 1. The first pass was made using a pulse rate of 1.5 hertz. This low pulse rate pass is used to consolidate the braze alloy powder. It has been found that if the initial pass uses higher heat input-higher pulse rate it will cause the braze alloy to ball up and not wet the surface. The second pass flows the braze alloy by using a 15 hertz pulse rate. The third pass uses the same 15 hertz pulse rate and further flows the braze alloy. The surface is blackened prior to the third pass with a marking pen. The blackened surface results in better coupling. This procedure is repeated adding more braze alloy powder until the desired fillet dimensions are produced. This may require as many as 5 to 6 repetitions depending on the size of fillet desired.

Two problems were encountered with our first effort. First, intergranular liquid metal stress cracking and liquid metal penetration of the grain boundaries such as can be seen in Figures 3 and 4 was noted in the metallographic examination. Second, the braze alloy pulled loose from the copper base material in a fashion such as is seen in Figure 6. The example shown in Figure 6 has been pressure tested to failure. The failure occurred somewhat below the desired strength. Macroexamination of several braze joints showed the braze alloy was also pulling loose from the copper substrate in the as-brazed condition. As can be seen, the failure is occurring in the copper.

A second series of braze joints were prepared leaving the silver plated layer intact. This is the arrangement shown in Figure 1. The braze alloy was changed to AWS BAu-4, again in the form of 200 mesh powder. The same laser parameters and procedures were used. Figure 5 shows a photomicrograph of a braze joint. The joint has been tested to failure and meet the desired strength requirements. The failure occurred in the silver plated layer. No intergranular cracking of the copper nickel was noted with the AWS BAu-4 braze alloy.

A microhardness survey of the recrystalized copper-nickel heat affected zone shows hardness values of R_B 77-79.5; the as-cold-worked area, R_B 88-91.5. Both structures can be seen in Figures 3 and 6.

DISCUSSION OF RESULTS

The AWS Brazing Manual (Ref. 1) recommends BAg filler metals for brazing copper-nickel alloys. The Brazing Manual also noted however, that "copper-nickel alloys are susceptible to intergranular penetration by molten filler metal in the stressed condition".

There are several conditions, which if present, increase the chances for the occurrence of liquid metal stress cracking (Ref. 3):

1. The liquidus temperature of the braze alloy is below the recrystallization temperature of the base material. In this case the liquidus temperature of AWS BAg-8 is 1435°F (779°C). The recrystallization temperature of copper-nickel can vary depending on the degree of cold work ranging from 1200°F for severly cold worked material to 1600°F (650°-871°C) for lightly cold worked material.

2. Brazing base metal which is in the as-cold-worked condition. Cold worked material has increased susceptibility because of the internal residual stress patterns set up. As noted, the copper-nickel tubing is in an as-cold-worked condition. Brazing in the annealed condition is recommended.

3. Unequal rapid heating which produces local thermal stresses. Using the pulsed laser with its high energy density certainly would be expected to produce high local stresses.

Interestingly enough we were able to avoid the liquid metal stress cracking problem by using a filler metal with a higher liquidus temperature (AWS BAu-4 - 1740°F (949°C)). This apparently allows stress relief and recystallization to occur before the braze alloy becomes molten. This avoids conditions (1) and (2). The stress created by the unequal rapid heating (3) is not sufficient to cause cracking without conditions (1) and (2) being satisfied.

It is unclear what caused the braze alloy to pull loose from the plated copper substrate. The weldability and brazability of plated substrates has not been extensively explored. Additional work is needed to resolve this problem.

REFERENCES

1. Brazing Manual, Third Edition, Feb. 28, 1975, American Welding Society, pg 181-182.

2. C. E. Witherell, T. J. Ramos, "Laser Brazing", Welding Journal, Oct. 1980, pg 363-373.

3. Joining Huntington Alloys, Fourth Edition, Huntington Alloys Inc., pg 46-47.

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TABLE 1
Laser Brazing Parameters

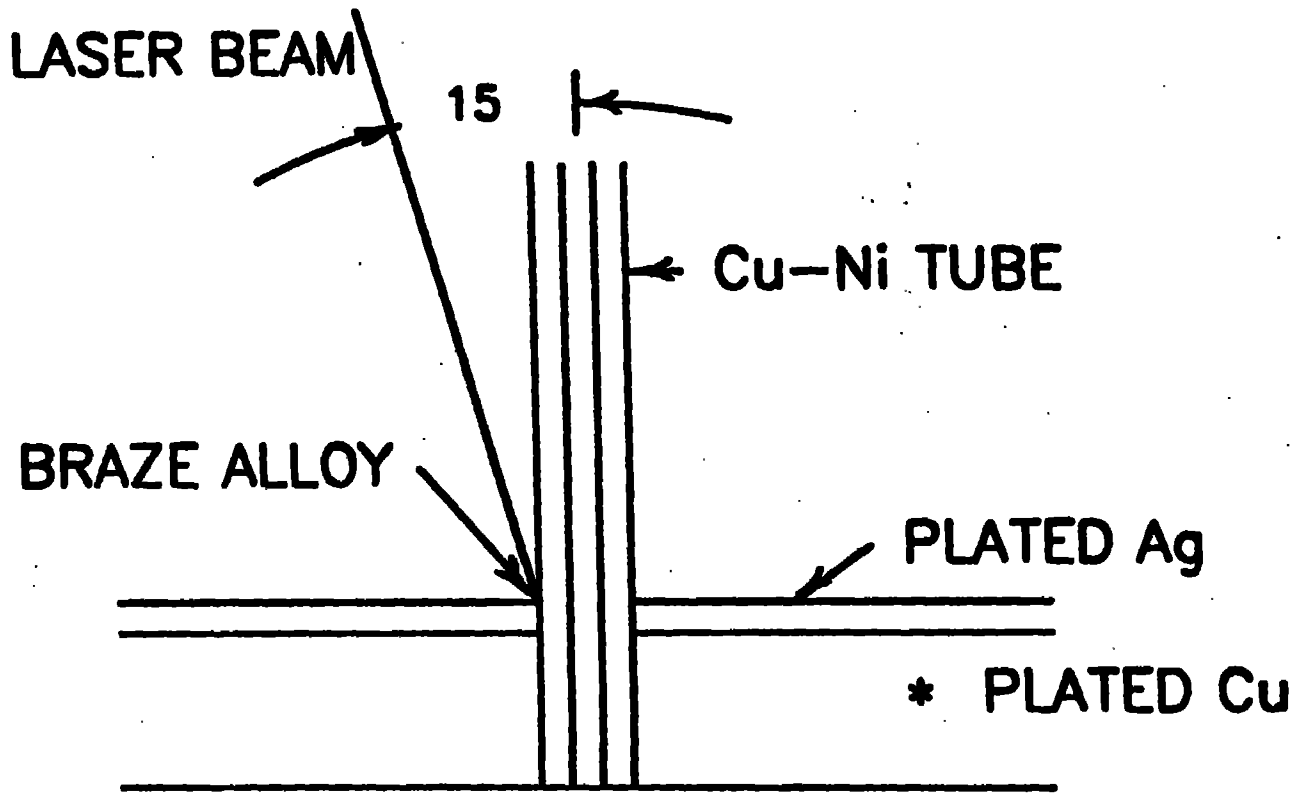
Laser Used - Raytheon SS500

	1st Pass	2nd Pass	3rd Pass*
Pulse Width (ms)	5	5	5
Internal Aperture (mm)	2.5	2.5	2.5
Pulse Rate (hertz)	1.5	2.5	2.5
Travel/Pulse (in.)	0.014	0.0014	0.0014
Time (sec)/Revolution	6	6	6
Lens (mm)	100	100	100
Gas Purge (Argon) (cfh)	5	20	20

*3rd Pass - surface blackened with a marking pen to improve laser coupling to surface.

Figure 1

SCHEMATIC DRAWING OF THE BRAZE



Magnification 50X

FIGURE 2

Copper-nickel tube laser tack welded onto plated copper substrate. The ammonium persulphate - HCl etchant used for the copper-nickel attacks the copper leaving it dark. Etchant: Ammonium persulphate - HCl

Magnification 200X

FIGURE 3

Liquid metal stress cracking of copper-nickel by AWS BAg-8 braze alloy. There is a very thin film of braze alloy on the surface. The main part of the braze is to the right on the photomicrograph. Etchant: Ammonium persulphate - HCl.

FIGURE 4

Magnification 500X

Liquid metal penetration of the grain boundaries by the AWS BAg-8 braze alloy. Etchant: Ammonium persulphate - HCl.

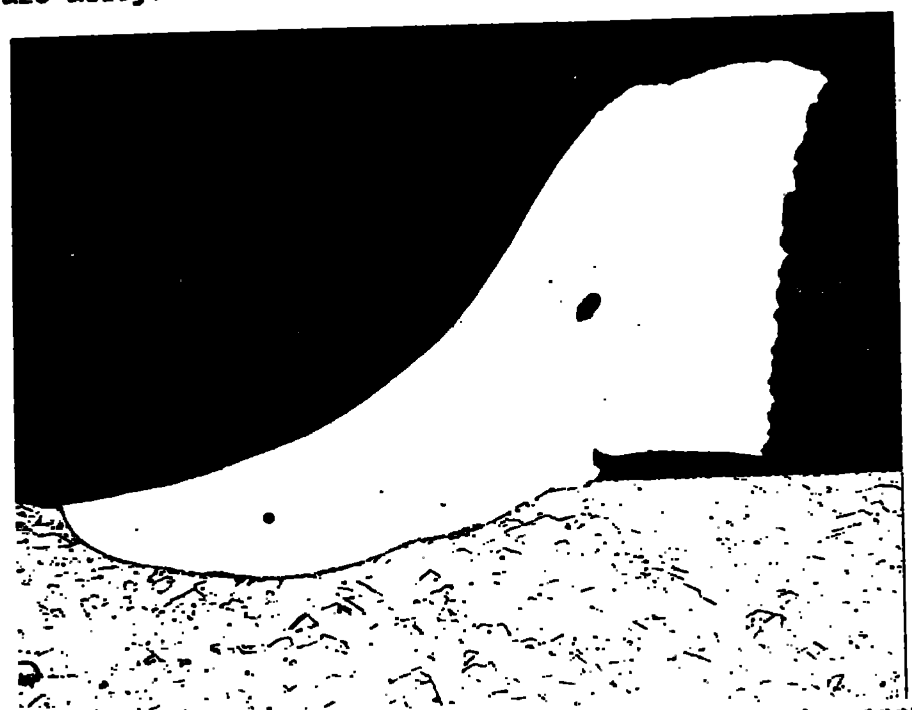


FIGURE 5

Magnification 100X

AWS BAu-4 braze tested to failure. Failure occurred in the silver plated substrate. No liquid metal stress cracking is apparent. Etchant: Ammonium persulphate - HCl.

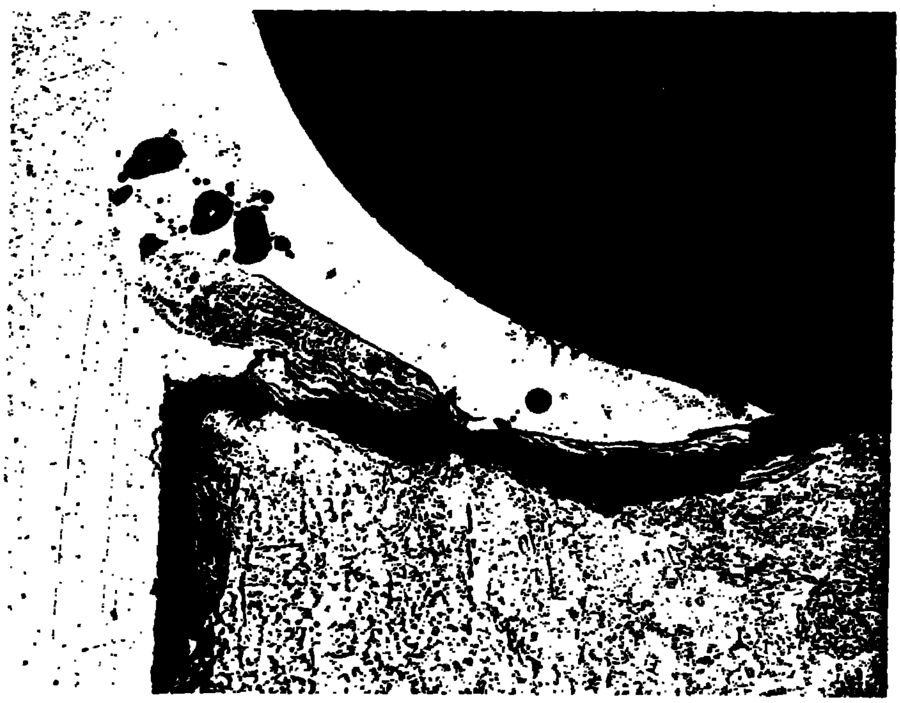


FIGURE 6 Magnification 200X

AWS BAu-4 braze on a plated copper substrate. The braze has been tested to failure. The failure occurred in the copper plated substrate. Note: no liquid metal stress cracking is seen in the copper-nickel base metal. Etchant: Ammonium hydroxide.